COMPARISON OF MANUAL AND AUTOMATIC DETECTION OF MUSCLE ACTIVATION MOMENTS

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Abstract: Detection of muscle activation moments is very important characteristic of human mobility. Muscle activation is used to describe how muscles work during some action. There are differences between muscle activation of healthy people and people suffering from neurodegenerative diseases or musculoskeletal disorders. The aim of this article is to compare results from manual and automatic detection of muscle activation moments from which driver reaction time is estimated. The main interest of this work is to find out if reaction time of healthy people differs from reaction time of people suffering by Parkinson disease.

1 INTRODUCTION

Reaction time of driver is one of the main characteristic of driver behavior and serves to traffic experts during investigation of traffic accidents. Driver reaction time describes driver behavior during braking, i.e for how long the driver responds by braking on a subject in his field of vision. Therefore, experts have been investigating the reaction time last twenty years, i.e how to measure reaction time, how to determine reaction time exactly, etc. Recent studies refer about acquisition of driver biosignals as a tool of traffic analysis, particularly about ECG, EEG and EMG [1], [2], [3], [4], [5].

There are two possible division of reaction time (mentioned below **Figure 1**). Older and less precise division of reaction is introduced firstly (the orange section). According to this division, reaction time consists of three parts, i.e visual, psychical and movement reaction time. Visual reaction time is bounded by moment of T_{ON} (the object appears in the driver's field of vision) and moment of T_F (driver fixates this object). Psychical reaction time starts at the moment of T_F and ends at the moment of T_A (moment when right lower limb releases accelerator). Movement reaction time is bounded by moment of T_A and T_B (moment of the first touch between right lower limb and brake pedal). How over twenty years of experience have shown this division of reaction time and values of its parts are inconclusive. Therefore, the alternative division of reaction time was created (blue section). According to this division, reaction time consists of three parts too, i.e visual reaction time, time needed to decision (T_D) and muscle response time (MRT). Visual reaction time is bounded by T_{ON} and T_F. too. Time needed to decision starts at the moment of T_F and ends at the moment of T_{EMG} (moment of muscle activation). Muscle response time is bounded by T_{EMG} and moment of T_B [6].

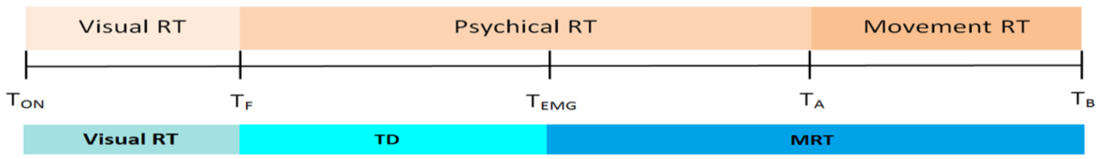

Figure 1: Two divisions of driver reaction time.

Acquisition of EMG signal from right lower limb can serve to more accurate determination of muscle response time, i.e to determine the entire reaction time.

The more accurate determination of reaction time could serve to improve traffic analysis and to assess what affects the duration of reaction time. This article is focused on muscle response time (as a part of entire driver reaction time) determination of healthy drivers and drivers suffering by Parkinson disease to find out how this neurodegenerative disorder affects driver behavior, i.e driver reaction time and its parts. But the main aim of this article is to introduce automatic detection based on pre-processing EMG signal by *Empirical Mode decomposition* and threshold setting.

2 METHODS AND DATA

Wireless device Cometa was used to acquire EMG signals from three muscles of right lower limb, i.e tibialis anterior, peroneus longus and triceps surae. Placement of electrodes is introduced below (**Figure 2**). Electrodes were placed in accordance with SENIAM standard [7].

Figure 2: Electrodes' placement.

2.1 ACQUIRED DATASET

Two groups of drivers were involved into our experiments, i.e group of healthy people and group of people suffering from Parkinson disease. Drivers took a 15-minute ride on the simulator and EMG signals from tibialis anterior, peroneus longus and triceps surae were acquired to determine their muscle response time. During riding, drivers had to brake every time an obstacle appeared in their field of vision (e.g. deer, pedestrian).

Final dataset contains 85 muscle response time values for healthy drivers and 60 muscle response time values of drivers suffering from Parkinson disease. Half of drivers suffering from Parkinson disease had normal cognition, the rest had cognitive impairment (mild or severe cognitive impairment). The initial number of drivers in both groups was 10.

2.2 EMPIRICAL MODE DECOMPOSITION (EMD)

Empirical Mode Decomposition is a method serving to processing of non-stationary signals and result of this method is a decomposition of signal into its intrinsic functions. Intrinsic functions have to fulfill two main conditions [8].

First condition is about number of extremes and zero passes. Number of extremes should be the same as a number of zero passes (or should differ by one). Second condition states that an average estimated from envelopes of local maxima and minima is zero (or very close to zero) at every time moment. Found intrinsic function of signal is one-component signal with zero mean value [9].

Firstly, envelopes for signal maxima and minima are estimated by cubic splines. Average signal calculated from these two envelopes can be defined as m_1. Calculated average signal is subtracted from the original signal and new component h_1 is the result of this step:

$$h_1 = X(t) - m_1. \tag{1}$$

For the currently found component h_1 two envelopes of maxima and minima are estimated again by cubic splines. Average signal is calculated between these two envelopes and is defined as m_{11}. In the next step, the average signal is subtracted from component h_1. Result of this last step is component h_{11}:

$$h_{11} = h_1 - m_{11}. \tag{2}$$

This process is repeated until the standard deviation for two consecutive components $h_{1(k-1)}$ and h_{1k} exceeds the set threshold (average signal m_{1k} should be zero or very close to zero):

$$SD = \sum_{t=0}^{T} \left[\frac{\left| h_{1(k-1)}(t) - h_{1k}(t) \right|^2}{h_{1(k-1)}^2(t)} \right] \tag{3}$$

If condition represented in equation (3) is fulfilled component h_{1k} is stated as first intrinsic function c_1 of the original signal:

$$\begin{gathered} h_{1k} = h_{1(k-1)} - m_{1k} \\ c_1 = h_{1k}. \end{gathered} \tag{4}$$

Next intrinsic function is performed similarly. First intrinsic function c_1 is subtracted from the original signal and new found component r_1 is stated:

$$r_1 = X(t) - c_1. \tag{5}$$

The entire process described above is repeated until the standard deviation threshold is fulfilled according to equation (3). Mathematical definitions and equations come from studies [9], [10], [11].

2.3 DETECTION OF MUSCLE ACTIVATION MOMENTS

Acquired EMG signals from all investigated muscles were given to an expert who marked moments of muscle activation manually. Simultaneously, own algorithm of EMD method was created and applied to the same EMG signals to pre-process them. First intrinsic functions of EMG signals were used for automatic detection of muscle activation moments and threshold was set depending on the standard deviation of the first intrinsic function baseline (i.e five times the standard deviation). Example of detections of EMG signal coming from m. tibialis anterior is shown in **Figure 3**.

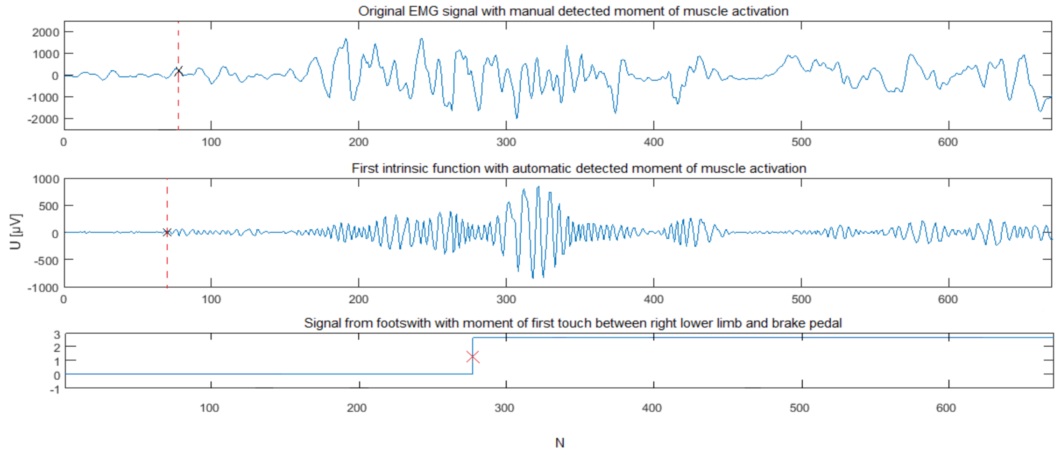

Figure 3: Manual/automatic detected moments of muscle activation.

2.4 STATISTICAL COMPARISON OF MANUAL AND AUTOMATIC DETECTION

Muscle response times of all three muscles, based on detected moments of muscle activation and moment of first touch between brake pedal and right lower limb, were performed to compare manual and automatic detection. Within the transport connoisseurship, there are no reference values of MRT, therefore results of both type of detection were compared using descriptive statistics.

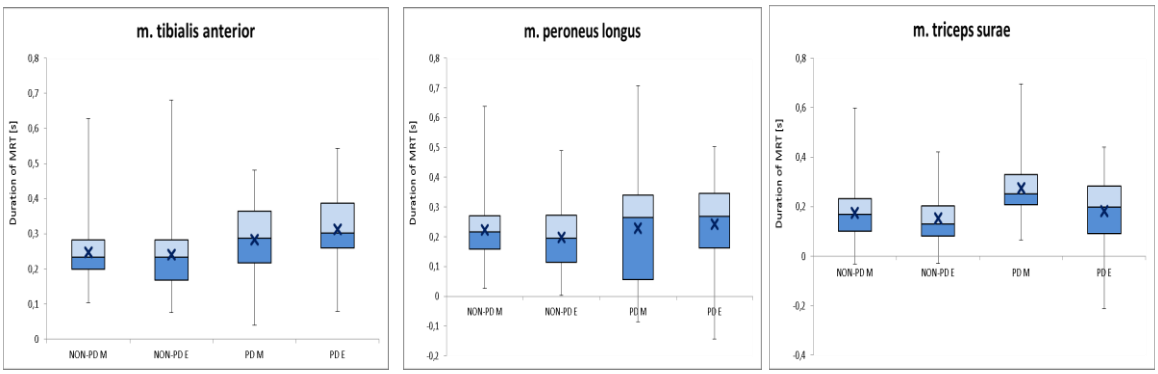

Figure 4: Box plots of MRT' values for all three muscles (maximum, minimum, quartiles and mean value).

In **Figure 4** box plots of MRT' values for all investigated muscles are shown. It turns out for both driver groups, tibialis anterior is the first muscle involved into braking because of the highest mean value of MRT. For the future work this fact is very important because EMG signal acquired only from m. tibialis anterior should be enough for accurate determination of entire reaction time.

Values of MRTs obtained from both detection approaches are very similar. Despite the fact that raw EMG signals were distorted by noise, expert marking moments of muscle activation had no significant problem with manual detection and results are similar.

The most important conclusion of this experiment is that MRT values for all investigated muscles are higher for drivers suffering by Parkinson disease. Therefore, it can be stated that entire reaction time is longer for drivers suffering by Parkinson disease. In **Table 1** the overview of statistic parameters of MRT values are introduced.

	MRT tibialis anterior [s]				MRT peroneus longus [s]				MRT triceps surae [s]			
	NON-PD M	NON-PD E	PD M	PD E	NON-PD M	NON-PD E	PD M	PD E	NON-PD M	NON-PD E	PD M	PD E
Mean	0,24742	0,24112	0,28333	0,3126	0,2229	0,19743	0,22858	0,24338	0,17439	0,15361	0,27575	0,18326
SD	0,08577	0,10326	0,10528	0,09774	0,10734	0,10532	0,17908	0,14691	0,09839	0,10506	0,10941	0,1387
Min	0,1035	0,0755	0,04	0,078	0,026	0,0025	-0,085	-0,143	-0,1155	-0,114	0,052	-0,1625
Q1	0,1988	0,16775	0,2165	0,26012	0,15862	0,11325	0,056	0,162	0,10087	0,08175	0,207	0,092
Median	0,2335	0,23325	0,288	0,30275	0,21675	0,1955	0,2645	0,2685	0,17	0,13025	0,251	0,1985
Q3	0,28262	0,28275	0,36375	0,38712	0,27125	0,27237	0,34	0,344875	0,23125	0,20375	0,3285	0,2825
Max	0,6285	0,6805	0,4805	0,543	0,6385	0,4895	0,708	0,503	0,5985	0,474	0,725	0,6395

Table 1: Main statistic parameters of MRT values.

3 CONCLUSION

Because of importance of traffic accident analysis, driver behavior and its characteristics are measured and investigated by new technologies and approaches. For this purpose, our experiment was performed too. In our case, it was examined whether neurodegenerative disorder (Parkinson disease) could affect the duration of driver reaction time. Especially, this work was focused on detection of muscle activation moments of three right lower limb muscles. It turns out that results from manual and automatic detection based on EMD are very similar, but manual detection is more intuitive and time-consuming.

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